

MAPS SHOWING STRUCTURAL INTERPRETATION OF MAGNETIC LINEAMENTS IN THE NORTHERN GULF OF ALASKA

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Magnetic contours - Dashed where inferred. Hachures indicate direction of decreasing intensity. Interval 50 gammas

Bathymetric contours, in meters - Hachures indicate direction of increasing depth

EXPLANATION

Magnetic lineament - Dashed where highly interpretive

Sea-floor spreading anomaly (Taylor and O'Neill, 1974)

Magnetic profile shown on Figure C

Bathymetric axis of Aleutian Trench

Land area

Land area
Glacier

Fault - Showing relative horizontal movement. Dashed where inferred

Thrust Fault - Dashed where inferred. Sawteeth on upper plate

Fault - Dashed where approximately located. U, upthrown side;
D, downthrown side

Anticline - Showing direction of plunge. Dashed where inferred

Syncline - Showing direction of plunge. Dashed where

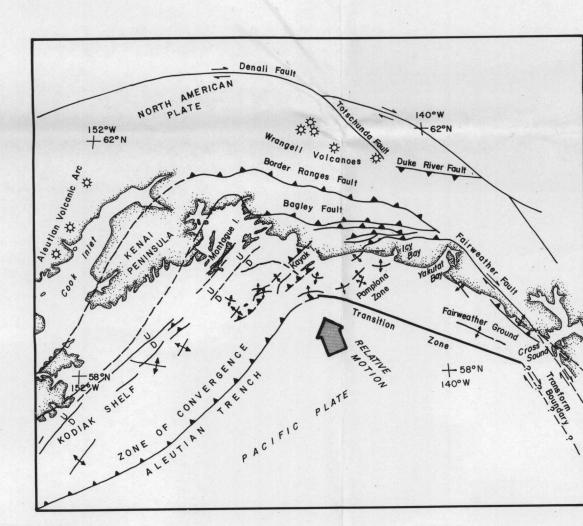
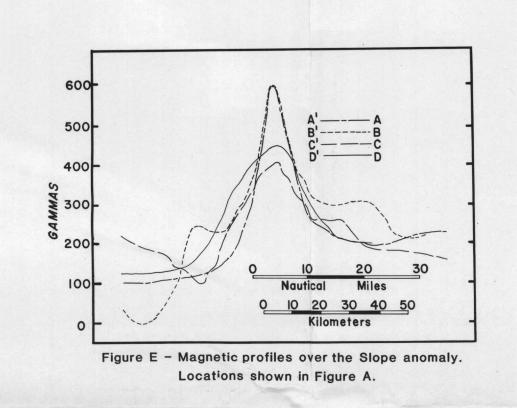
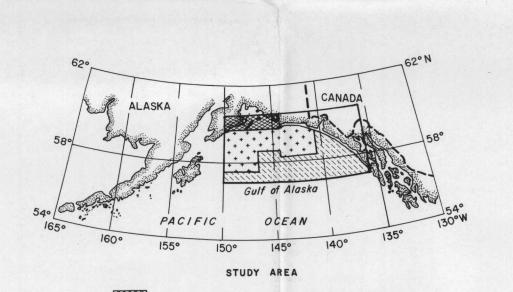


Figure D - Generalized tectonic setting of the northern Gulf of Alaska (after Bruns, 1979)





INTRODUCTION

This report presents a structural interpretation of magnetic lineaments in the Gulf of Alaska north of 57°N. Magnetic lineaments are identified, and magnetic and seismic data are used to select magnetic anomalies that appear to be structurally significant. Magnetic lineaments in the Gulf of Alaska have been previously discussed by Haines, Hannaford, and Riddihough (1971), von Huene (1972), Naugler and Wageman (1973) and Taylor and O'Neill (1974). Two of the earlier studies by Naugler and Wageman (1973) and Taylor and O'Neill (1974) were primarily concerned with linear anomalies that are typical of oceanic crust. Schwab and Bruns (1979) compiled magnetic data on a part of the continental shelf, porthern Gulf of Alaska, from surveys by the National Oceanographic and Atmospheric Administration (R/V Surveyor marine magnetic survey, available through the National Geophysical and Solar-Terrestrial Data Center, Boulder, Colorado) and the U.S. Geological Survey (M/V C.H. Green and R/V S.P. Lee marine magnetic surveys, available through the U.S. Geological Survey, Office of Marine Geology, Menlo Park, California). The magnetic maps of Taylor and O'Neill (1974), and Schwab and Bruns (1979) along with U.S. Geological Survey aeromagnetic maps (J. E. Case, written commun., 1979), are compiled on figure A.

The following summary of the geologic setting is based on publications on the geology and structure of the northern Gulf of Alaska including von Huene and others (1979a,b), Plafker (1974), Plafker and others (1978a,b), Rodgers (1977), and Bruns (1979).

On the basis of geological and structural data, the continental margin in the northern Gulf of Alaska can be divided into three distinct segments (Plafker and others, 1978a; Bruns, 1979). The three segments are separated by

East of the Pamplona zone, late Cenozoic rocks underlying the continental shelf are generally undeformed (fig. B). However, local deformation occurs along a narrow zone near Lituya Bay, as an anticline offshore of Dry Bay, at the west end of Fairweather Ground, and at the shelf edge south of Yakutat Bay. Between the Pamplona and Kayak Island zones, the continental margin is characterized by broad folds and associated thrust faults (Bruns, 1979). Multichannel seismic data suggest that late Cenozoic folds become younger to the southeast. Thus, the Pamplona zone is the youngest site of late Cenozoic deformation along the continental margin (Rogers, 1977; Bruns, 1979). Late Cenozoic structures mapped on Kayak Island (Plafker, 1974) trend across the continental shelf forming the Kayak Island zone (fig. B). Kayak Island is a major zone of thrusting and structural shortening. The Kayak Island zone may be a deformed and older analog to the Pamplona zone. The structural features of the continental shelf west of the Kayak Island zone are significantly more complex than those of the shelf east of the Kayak Island zone. Deformation of the shelf west of the Kayak Island zone. Deformation of the shelf west of the Kayak Island zone to northwestward

Magnetic lineaments are presumed to be due to contacts between geologic units of differing rock magnetizations. Three types of magnetic lineaments are distinguishable in the Gulf of Alaska (fig. C): (1) those along the peak or trough of an elongate anomaly; (2) those that lie along sharp magnetic gradients; and (3) those that delineate magnetic discontinuities. Lineaments along magnetic discontinuities are drawn along aligned changes in magnetic character. Lineaments of magnetic discontinuity tend to be structurally significant (Barosh, 1972; Barosh and others, 1974). Magnetic lineaments in the Gulf of Alaska are herein informally named to simplify discussion.

compression appears to have been generally continuous during late Cenozoic

time (Bruns, 1979).

The most striking magnetic feature of the Gulf of Alaska is the abrupt separation of the north-trending oceanic anomalies (Vine and Matthews, 1963) from the continental shelf anomaly pattern along the Slope anomaly, a northwest-trending, elongate, and positive anomaly (fig. C). The Slope anomaly trends N.65°W. from Alsek Canyon to Kayak Island along the continental slope and N.80°W. from Kayak Island to Montague Island over the continental shelf (Haines and others, 1971; Naugler and Wageman, 1973; Taylor and O'Neill, 1974; Schwab and Bruns, 1979). From southeast to northwest, the Slope anomaly is interrupted by several magnetic lineaments over the continental shelf, for example, the Icy Bay lineament, the Yakutat disturbed zone, possibly the Bering Trough lineament, and the Kayak Island lineament. Data are sparse west of Montague Island, but termination of the Slope anomaly may be associated with the offshore extension of a magnetic lineament trending along the east coast of Resurrection Bay.

Magnetic Lineaments of the Continental Shelf Five magnetic lineaments that trend across the continental shelf are interpreted on the basis of subtle magnetic anomaly alignments. From east to west these alignments are (1) the Alsek Canyon curvilinear; (2) the Icy Bay lineament and Yakutat disturbed zone; (3) the Bering Trough lineament, (4) the Kayak Island lineament; and (5) the Ragged Mountain lineament (fig. C). Alsek Canyon Curvilinear and Fairweather Anomaly: The Fairweather anomaly is an area of high-frequency, high-amplitude magnetic anomalies over the continental shelf south of Dry Bay (fig. C). A magnetic high within the Fairweather anomaly occurs over a structural high centered on Fairweather Ground (fig. B). From east to west, the magnetic high broadens and becomes increasingly more distorted, reaching a maximum in complexity along a northeast to northwest-trending curvilinear magnetic discontinuity termed the Alsek Canyon curvilinear. The Alsek Canyon curvilinear forms the eastern boundary of an area of the continental shelf between 139°W. and 141°W. that is dominated by northwest-southeast magnetic trends (fig. A). The westward termination of the Fairweather anomaly against the Alsek Canyon curvilinear coincides with and may result from a zone of early Cenozoic structural deformation at the west end of Fairweather Ground (fig. B). Multichannel seismic-reflection data are sparse in the area of the Fairweather anomaly (Bruns, 1979). However, a zone of deformation affecting Cretaceous and early Tertiary rocks is present near Alsek Canyon (fig. B) and generally coincides with the Alsek Canyon curvilinear. Because this zone does not appear to have affected late Cenozoic rocks, the Alsek Canyon curvilinear appears to be associated with a pre-late Cenozoic structural feature. Taylor and O'Neill (1974) estimated the depth to the magnetic source beneath Fairweather Ground to be between 2.2 and 2.3 km. Correlation of dredge data from the continental slope (Plafker and others, 1978c) with multichannel seismic-reflection data (Bruns, 1979) suggests that rocks at this depth are a deformed, metamorphosed, and intruded flysch and melange sequence of late Jurassic (?) to late Cretaceous age, typical of the Yakutat Group on the adjacent mainland. Therefore, the source of the Fairweather anomaly is O'Neill (1973) interpreted the magnetic high over Fairweather Ground as the southeastern extent of the Slope anomaly. Preliminary two-dimensional

modeling of gravity and magnetic data south of Icy Bay suggests that the source of the Slope anomaly is at a depth of at least 6 km. The difference in magnetic intensity and pattern, and in the depth to the source between the Slope anomaly and the Fairweather anomaly, suggests either that the Slope anomaly and the Fairweather anomaly are not related, or that significant prelate Cenozoic uplift of the source body has occurred beneath the Fairweather anomaly, with the Alsek Canyon curvilinear marking the uplift boundary.

Icy Bay Lineament and Yakutat Disturbed Zone: A broad magnetic low is observed southeast of Icy Bay (fig. A). A magnetic lineament, termed the Icy Bay lineament, extends along the southwest flank of the magnetic low. The Icy Bay lineament forms the western boundary of an area of the continental shelf between 139°W. and 141°W. that is dominated by northwest-southeast magnetic trends (fig. A). The southeast extension of the Icy Bay lineament across the shelf break may disrupt the Slope anomaly. Alternatively, the Icy Bay lineament could be interpreted to intersect the shelf break farther west within the Yakutat disturbed zone, an anomalous area at the mouth of the Yakutat Seavalley characterized by high-frequency magnetic anomalies. The Icy Bay lineament and Yakutat disturbed zone are not related to any known late Cenozoic structures, suggesting that these features are caused by pre-late

Cenozoic structures, suggesting that these features are caused by pre-late Cenozoic structural features.

Bering Trough Lineament: A northeast-trending, poorly defined lineament of magnetic discontinuity extends across the Bering Trough and is informally termed the Bering Trough lineament (fig. B). The lineament separates a broad, higher amplitude anomaly to the west from a zone of low-amplitude, irregular magnetic anomalies to the east.

Late Cenozoic structures tend to change in trend and die out from east to west across the Bering Trough lineament (Bruns, 1979). Refraction velocities in basement rocks west of the Bering Trough lineament are higher than corresponding velocities from the area east of the lineament (Bayer and others, 1978). The differences in refraction velocities, in magnetic anomaly patterns, and in the structural character of late Cenozoic deformation suggest that the basement rocks west of the Bering Trough lineament are more strongly lithified (Bayer and others, 1978) and have a substantially different magnetic character. Therefore, the Bering Trough lineament appears to be associated

with a fault or contact between two types of basement rock.

If the Bering Trough lineament extends to the southwest across the shelf break, it sharply cuts the Slope anomaly at 143.5%, 59.4°N. Alternatively, this break corresponds to the intersection of the Slope anomaly and the

Kayak Island Lineament: A northeast-trending magnetic lineament termed the Kayak Island lineament is located over the Kayak Island zone (fig. B). The seaward expression of the Kayak Island lineament could be interpreted to abut against a part of the Slope anomaly (fig. C). Alternatively, the Kayak Island lineament may bend to the west, cutting and possibly offsetting the Slope anomaly at 59.5°N., 145.6°W. This interpretation would be analogous to the westward bending of the Pamplona zone. West of the Kayak Island lineament, the magnetic anomalies over the continental shelf are attenuated approximately 100 gammas relative to the magnetic anomalies east of the Kayak Island lineament (fig. A; fig. E).

Ragged Mountain Lineament: A structural block bordered on the south by a major northwest-striking thrust fault, on the east by the Kayak Island zone, and to the north by the northeast-striking offshore extension of the Ragged Mountain fault, lies west of Kayak Island (fig. B; Bruns, 1979). Magnetic anomalies over this structural block have higher frequencies and higher amplitudes than those in the surrounding area. Magnetic discontinuities are associated with all the faults bordering this structural block. The offshore extension of the Ragged Mountain fault is therefore magnetically represented by a lineament termed the Ragged Mountain lineament (fig. C).

Oceanic Magnetic Lineaments

Seaward of the Slope anomaly, the Gulf of Alaska is dominated by sea floor spreading anomalies (fig. C; Vine and Matthews, 1963; Pitman and Hayes, 1968; Atwater and Menard, 1970). Oceanic anomalies 7 through 20 on the Heirtzler and other (1968) time scale are identified on figure C following Taylor and O'Neill (1974).

Between 145°W. and 148°W., the north-trending oceanic anomalies are right laterally offset at 58°N. along the 58° magnetic discontinuity (fig. C; Taylor and O'Neill, 1974). This offset is interpreted as representing the expression of an east-trending paleotransform fault or fracture zone (von Huene, 1972). Between 143°W. and 145°W., the 58° magnetic discontinuity trends N.40°W. West of 145°W., the 58° magnetic discontinuity trends east-west. The bend in the 58° magnetic discontinuity occurs between oceanic anomalies dated between 37.4 and 39.1 m.y. (LaBrecque and others, 1977). This bend may represent an adjustment of a paleotransform fault in response to a change in spreading direction, similar to the method proposed by Menard and Atwater (1968). The changes in spreading direction and associated change in trend of the 58° magnetic discontinuity may also correlate with a bend in the Emperor Seamount

Sea-floor spreading anomalies can be traced across the Aleutian Trench over the Kodiak shelf segment of the continental margin; this evidence suggests subduction of the Pacific plate beneath the North American plate (fig. C; Heirtzler, 1970; von Huene, 1972; Taylor and O'Neill, 1974). The subducted sea-floor spreading anomalies are attenuated, presumably due to a greater depth of burial.

Chain dated at 41.7 m.y. (Jackson and others, 1975).

Haines and others (1971) noted that magnetic anomalies either terminate, are distorted, or are reduced in amplitude in a zone as much as 50 km wide between 143°W. and 135°W. (fig. C). This area was termed the "smooth zone" by Naugler and Wageman (1973); however, we prefer to call it the attenuated zone since oceanic anomalies may be present within this area, although severely reduced in amplitude. The attenuated zone is bordered to the north by the Slope anomaly and Fairweather anomaly and to the south by a magnetic discontinuity termed the attenuated zone transition. Possible explanations of attenuation of anomalies in the attenuated zone have been offered by Naugler and Wageman (1973) and von Huene and others (1979b), but the causes remain

DISCUSSION

The present tectonic regime in the northern Gulf of Alaska presumably results from relative northwest convergence between the Pacific and North American plates (Plafker and others, 1978b; fig. D). The northern Gulf of Alaska is in a zone of transition between transform motion along the Queen Charlotte and Fairweather fault systems and convergent motion at the Aleutian Trench (Plafker, 1969). If the late Cenozoic relative convergence vector of about N.15°W. at 6 cm/yr between the Pacific and North American plates is valid (Minster and Jordan, 1978; Chase, 1978), then large amounts of displacement are implied between the two plates. Studies onshore indicate that the combined displacement on both the Fairweather and Denali faults is small, about 10 km, during late Cenozoic time. Therefore, the necessary displacement is presumed to occur offshore, possibly along the Transition zone (Plafker and others, 1977, 1978b). Relative convergence between the two plates also implies that the Transition zone should be a zone of oblique subduction. However, no deformation or accretion related to this presumed oblique subduction has been recognized in the upper crust from multichannel seismic-reflection data (Bruns, 1979).

On the basis of magnetic data, and with the exception of the attenuated zone, the northern Gulf of Alaska is divisible into two areas. One area is characterized by a prominent oceanic magnetic pattern and the other by a subdued pattern representing the continental shelf. Thus, we assume that the crust with oceanic affinities and crust with continental affinities are represented by the distinct anomaly patterns. These patterns are separated by a prominent linear magnetic high, the Slope anomaly. The general coincidence of the eastern part of the Slope anomaly with the Transition zone from 141°W. to 144°W., suggests that the Slope anomaly may be associated with the inferred fault zone. The age of this feature can be inferred from relations with structures of known age.

Magnetic and seismic-reflection data define oblique—and transverse—

Magnetic and seismic-reflection data define oblique- and transverse-trending structures of the continental shelf that appear to affect the Slope anomaly. The axis of the Slope anomaly has negative saddles or zones of disruption where the Icy Bay lineament, Yakutat disturbed zone, possibly the Bering Trough lineament, and Kayak Island lineament project from the shelf across the slope. The Slope anomaly is also terminated to the southeast by the Alsek Canyon curvilinear. The Kayak Island lineament corresponds to a transverse compressional structure that is thought to have developed primarily during the late Cenozoic (Plafker and others, 1978b; Bruns, 1979). The disruption of the Slope anomaly along the Bering Trough lineament could be caused by the intersection of the anomaly with the Pamplona zone, another late Cenozoic transverse compressional structure, or by a fault or contact between two types of basement rock that possibly causes the Bering Trough lineament However, there are no late Cenozoic structures associated with the Icy Bay lineament or the Yakutat disturbed zone. Also, the Alsek Canyon curvilinear is thought to be caused by a basement feature disrupting Cretaceous (?) and early Tertiary rocks, but not affecting overlying late Cenozoic strata. Therefore, from the crosscutting relations, the rocks causing the Slope anomaly are pre-late Cenozoic in age. West of the Kayak Island zone, the Slope anomaly does not follow the

continental slope but trends across the continental shelf for 160 km. In this area, the Slope anomaly is attenuated (fig. E) in a manner similar to the attenuation of the oceanic anomalies northwest of the Aleutian Trench. Attenuation of the Slope anomaly west of Kayak Island suggests a greater depth to the magnetic source than is observed east of Kayak Island. If the Slope anomaly is not a fortuitous alignment of two linear magnetic trends and if the attenuation of the Slope anomaly west of Kayak Island is due to a greater depth to the magnetic source, then the source, along with oceanic crust south of the Slope anomaly, has been subducted beneath the continental shelf west of Kayak Island (Schwab and others, 1979; Bruns and others, 1979).

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